



PATENT

IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

The Application of:
Steinke, et al.

Serial No.: 07/953,680

Filed: September 29, 1992

For: METHOD AND APPARATUS FOR
DIRECT SPECTROPHOTOMETRIC
MEASUREMENTS IN UNALTERED
WHOLE BLOOD

§ Group Art Unit: 2505
§ Examiner: K. Hantis
§ Atty Dkt.: UTSK:142/BAH

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GROUP 2600

CERTIFICATE OF MAILING
37 C.F.R. I.8

I hereby certify that this correspondence is being deposited with the U.S. Postal Service as First Class Mail in an envelope addressed to: Commissioner of Patents and Trademarks, Washington, D.C. 20231, on the date below:

3/24/94

Date

David D. Bahler

DECLARATION UNDER 37 C.F.R. § 1.132

Honorable Commissioner of Patents
and Trademarks
Washington, D.C. 20231

Sir:

I, ROLAND N. PITTMAN, a citizen of the United States, hereby declare and state:

1. I have an S.B. degree in Physics, which was conferred upon me by the Massachusetts Institute of Technology in 1966, an M.A. and Ph.D. degrees in Physics which were conferred upon me by the State University of New York in Stony Brook, in 1968 and 1971, respectively.

2. I have been employed by the Medical College of Virginia, Virginia Commonwealth University, since 1974 and am presently a professor of physiology and biomedical engineering.

3. I have been involved in the study of the optical properties of hemoglobin and oxygen transport in the microcirculatory system. I have authored numerous articles on the topics of microcirculation and blood flow, and have developed and used optical methods for the measurement of hematocrit and oxyhemoglobin concentration in blood. Attached to this declaration is my *Curriculum Vitae*, which summarizes my education and employment, and which includes a listing of my publications.

4. I have read the above-identified application, including claims 1-33, have read the Office Action mailed by the United States Patent and Trademark office on October 1, 1993, and have read the reference applied by the Examiner to reject claims 1-33, (*Anderson et al.*, "Light-Absorbing and Scattering Properties of Non-Haemolysed Blood," *Phys. Med. Bio.*, Vol. 12, 2:173-184 (1967)).

5. The purposes of the *Anderson et al.* reference as stated by *Anderson et al.* (page 174, second full paragraph) was:

- "(a) to investigate the light-scattering and light-absorbing property of non-haemolyzed blood,
- (b) to evaluate separately the amount of light absorbed and the amount scattered by thin layers of flowing non-haemolyzed blood by applying a theory for the multiple scattering of waves, and
- (c) to test the general validity of the empirical relationships between OD[optical density] and haemoglobin content (eqn. (1))."

The theory used was that of Victor Twersky. Not stated among the purposes of *Anderson et al.* was the determination of hemoglobin concentration from optical density.

6. Although *Anderson et al.* do not completely explain, it is readily apparent that *Anderson et al.* measured the OD of non-hemolyzed blood and made independent measurements of hemoglobin concentration [Hb] by some unspecified means. They then used curve-fitting techniques and employed arbitrary values for various parameters in Twersky's equation (*Anderson et al.*, Eqn. 5, page 175). The parameters in Twersky's equation that were set to arbitrary constant values include the parameters s and q_a/q (*Anderson et al.*, page 180, last paragraph).

7. In this way, *Anderson et al.* deduced the relative contributions that light scattering and true optical absorbance made to the optical attenuation of a particular sample of non-haemolyzed blood.

8. Contrary to the patent examiner's understanding of the *Anderson et al.* reference, *Anderson et al.* did not develop a practical method for deducing hemoglobin concentration from optical density. In fact, for simple mathematical reasons, it is impossible to solve Twersky's equation, used by *Anderson et al.*, for a sample of whole blood of unknown composition. The reason for this mathematical impossibility is that Twersky's equation contains too many parameters for which there is no known value in a sample of whole blood of unknown composition.

9. Specifically, Eqn. 5 of *Anderson et al.* requires specific values for the parameters K' , s and q_a/q , which together quantify: the refractive index of plasma, the refractive index of red cells, and the factor L which depends on the size and shape of red blood cells. Because each

of these factors can vary in an unpredictable way from one blood sample to another, it is not possible to solve Twersky's equation for hemoglobin concentration in a sample of whole blood of unknown concentration.

10. Furthermore, Twersky's equation is a theoretical description of ideal whole blood that does not accommodate causes of scattering other than red blood cells. Other factors that influence light scattering in a sample of whole blood of unknown composition include: the different plasma protein concentrations that determine the refractive index of plasma in one sample vs. another; the aggregation of red blood cells in the sample; the different hemoglobin concentrations inside the red blood cells that alter their refractive index; the size and shape of the red blood cells; chylomicrons or other light-scattering lipid particles; cell fragments; microscopic clots; light-sieving effects of sedimented red blood cells; and partial hemolysis.

11. In addition, it should be noted that in order to generate their curves, *Anderson et al.* must necessarily alter the hemoglobin concentration of the samples under study. According to *Anderson et al.* altered hemoglobin concentration is accomplished by suspending fully oxygenated non-hemolyzed red cells in isotonic saline (*Anderson et al.*, page 177, second paragraph).

12. In the 27 years since the publication of the *Anderson et al.* paper, four companies have developed so-called co-oximeters that measure the total hemoglobin concentration and relative concentration of four hemoglobin species (Instrumentation Laboratory, Ciba Corning, Radiometer and AVL). In each case, the instrument is designed to hemolyze the sample first before subjecting it to spectrophotometric analysis.

13. To the best of my knowledge, the invention of the subject patent application is the first to succeed in making these measurements directly in whole blood without hemolysis, and thus has tremendous advantages over the prior art, including *Anderson et al.* In particular, the present invention will lower manufacturing costs due to the elimination of pumps, plumbing, and hemolyzers; the invention provides a non-destructive measurement that allows the sample with intact red cells to be subjected to further hematological or other analyses; and the invention permits a compact, rugged design.

14. The prior art references of which I am aware, including *Anderson et al.*, do not teach to one of ordinary skill in this technology and do not teach to me personally, how to make or use the invention claimed in the above-identified U.S. patent application. Moreover, even in view of the scope and content of the disclosure of that prior art, the invention as claimed in this application as a whole would not have been obvious at the time the invention was made to a person having ordinary skill in this technology.

15. I hereby declare that all statements made herein of my own knowledge are true, and that all statements made on information and belief are believed to be true; and further that these statements were made with the knowledge that willful, false statements and the like are punishable by fine and/or imprisonment under Section 1001 of Title 18 of the United States Code, and that such willful false statements may jeopardize the validity of the above-identified application, or any patent issuing therefrom.

2/28/94
Date

Roland N. Pittman
Roland N. Pittman



CURRICULUM VITAE

ROLAND N. PITTMAN, PH.D.
(UPDATED 1 MARCH 1994)

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1. PERSONAL INFORMATION

- 1.1 Roland Nathan Pittman
- 1.2 February 13, 1944
Waco, Texas
- 1.3 American Citizen
- 1.4 413-70-4327
- 1.5 married, two children
- 1.6 1205-3B Buckingham Station Drive
Midlothian, Virginia 23113
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- 1.7 Department of Physiology
P. O. Box 980551
Virginia Commonwealth University
Richmond, Virginia 23298-0551
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E-mail: PITTMAN@GEMS.VCU.EDU

2. LICENSURE

None

3. EDUCATION

State University of New York Ph.D. (Physics) 1971
Stony Brook, New York M.A. (Physics) 1968

Massachusetts Institute of Technology S.B. (Physics) 1966
Cambridge, Massachusetts

National Science Foundation Predoctoral Traineeship: 1966-1971
Alfred P. Sloan Scholarship: 1962-1966

4. MILITARY SERVICE RECORD

None

5. POSTDOCTORAL TRAINING

Postdoctoral Trainee and Fellow, Department of Physiology, University of Virginia, Charlottesville, Virginia, with Dr. Brian R. Duling (Oxygen sensitivity of vascular smooth muscle and oxygen transport in the microcirculation): 1971-1974

6. ACADEMIC APPOINTMENTS

Professor of Physiology, Medical College of Virginia, Virginia Commonwealth University, Richmond, Virginia, 1987-present.

Professor of Biomedical Engineering, Medical College of Virginia, Virginia Commonwealth University, Richmond, Virginia, 1992-present.

Associate Professor of Physiology, Medical College of Virginia, Virginia Commonwealth University, Richmond, Virginia, 1978-1987.

Assistant Professor of Physiology, Medical College of Virginia, Virginia Commonwealth University, Richmond, Virginia, 1974-1978.

7. MEMBERSHIP IN SCIENTIFIC, HONORARY AND PROFESSIONAL SOCIETIES

American Heart Association, Council on Basic Science

American Physiological Society; Fellow, Cardiovascular Section

Biomedical Engineering Society

Biophysical Society

European Society for Microcirculation

International Society on Oxygen Transport to Tissue

Executive Committee, 1989-1990, 1993-1996

Microcirculatory Society

Executive Council, 1981-1984; Secretary, 1987-1991; President-Elect, 1992-1993; President, 1993-1994

North American Society for Biomechanics

Sigma Xi

Virginia Academy of Science

8. MEMBERSHIP IN COMMUNITY ORGANIZATIONS

Bon Air Baptist Church

9. SPECIAL AWARDS, FELLOWSHIPS AND OTHER HONORS

9.1 Research Awards

Pharmacia Travel Award, Microcirculatory Society, 1976

National Research Council, Travel Award to 27th International Congress of Physiological Sciences, Paris, 1977

Louis N. Katz Basic Science Research Prize for Young Investigators, American Heart Association, 1979

IPM, Inc. Innovative Instrumentation Award, Microcirculatory Society, 1989 (shared with C. G. Ellis and M. L. Ellsworth)

9.2 Fellowships

None

9.3 Teaching Awards

Professor of the Year, M-I: 1980, 1982, 1985

Best Professor, M-I Cardiovascular: 1984, 1985, 1987

Best Professor, M-I Respiratory-Renal: 1984, 1985, 1986

9.4 Service Awards

Five Years Service, American Heart Association, Virginia Affiliate, 1989

Outgoing Chairperson, Research Peer Review Subcommittee, American Heart Association, Virginia Affiliate, 1991

Outstanding Service Contributions, Microcirculatory Society, 1991, 1994

9.5 Other Honors

American Men and Women of Science: 1976-present

Who's Who in the South and Southwest: 1978-present

Who's Who in Science and Engineering: 1992-present

Nominee, VCU Riese-Melton Award: 1986, 1987, 1988

10. MAJOR COMMITTEES

10.1 University

Tenure/Promotion Committee: 1978, 1983(2), 1984(3), 1989(2), 1990(2), 1991(2), 1993

Institutional Research Advisory Committee: 1979-1982

University Grievance and Appeals Boards and Panels: 1983-1986, 1991-

1994

School of Basic Health Science Faculty Committee: Chairman, 1985-1987

Agenda Committee, School of Basic Health Sciences: 1985-1987

University Academic Planning Committee: 1986-1989

Medical Curriculum Reform Steering Committee: 1986-1987

Physiology Chair Search Committee: 1987-1988

Biomedical Engineering Program Director Search Committee: 1988

Biomedical Engineering Advisory Committee: 1988-1990

Professorial Advisory Committee, SBHS: 1989-1990

Confidential Aid to Impaired Students Committee (CAIS): 1993-present

Academic Planning Committee, School of Engineering: 1994-present

M.S. Thesis Committees: Irene P. Walsh (1975), Marilyn Fishel (1976), Howard W. Stuart, Jr., (1976), Permsak Komwatana (1978), Mark D. Okusa (1978), James V. Quinn (1978), Tina Chen (1980), James M. Smith (1980), Robin A. Silva (1981), William H. Blackwell (1982), Florence Neal-Cooper (1984), Richard A. O. Bennett (1988), Yang Han (1989), Kathy Kuelz (1991), Christopher J. Hyatt (1992), Elizabeth A. Mott (1992), Mark Annett (1993), Kaushik Parthasarathi (1993), Daniel W. David (1994), Richard Gill (1994), David Kagey (1994).

Ph.D. Thesis Committees: John T. Earnhardt (1976), Virginia H. Huxley (1980), Kathleen L. Kelly (1982), James W. Moore, III (1983), David P. Swain (1984), Ralph G. Crawford (1984), John M. Kennedy (1984), Scott Duncan (1986), Vicky L. Y. Wong (1986), Lih Kuo (1987), Yvonne P. Dragan (1988), Joanne Less (1989), Samuel C. Dudley (1991), J. Christopher Stein (1994).

Ph.D. Oral Comprehensive Exam Committees: S. Randall Thomas (1976), Richard Greenberg (1977), Scott Loveless (1978), James W. Moore, III (1980), J. Scott Brockenbrough (1981), A. Nader Rifai (1983), John M. Kennedy (1983), David P. Swain (1983), Daniel Gamache (1983), Scott Duncan (1984), Vicky Wong (1985), Yvonne P. Dragan (1986), Lih Kuo (1986), Steingrimur Stefansson (1988), Justicia Opoku (1989), Samuel Dudley (1989), Shunlin Ren (1991), J. Christopher Stein (1991), Jennifer E. Visich (1993).

10.2 Departmental Committees

Committee on Graduate Curriculum (Chairman): 1975

Seminar Program (Chairman): 1975-1976

Committee on Graduate Programs (Chairman): 1976-1977

Committee on Laboratory Teaching (Chairman): 1983-1984

Graduate Admissions Committee: 1984-1985

Programs Committee (Chairman): 1985-1986

Committee on Affiliate Faculty (Chairman): 1985-1988

Graduate Recruitment and Admissions Committee: 1989-present

Credentials Committee (Chairman): 1993-present

10.3 National Committees

Microcirculatory Society: Nominating Committee (1977-1978, 1985-1987 (chairman)), Awards Committee (1978-1979, 1980-1981, 1981-1983 (chairman)), Finance Committee (1983-1986), Liaison Committee (1988-present), Program Committee (1992-1993 (chair)), Long Range Planning Committee (1994-present)

American Heart Association, Virginia Affiliate: Research Committee (1989-1993)

National Research Council, Commission on Life Sciences, U.S. National Committee for the International Union of Physiological Sciences (1990-1993)

10.4 International Committees

International Program Committee of Fifth World Congress for Microcirculation (1990-1991)

11. Other Significant Scholarly, Research or Administrative Experience

11.1 Teaching

Pharmacy Physiology: 1974-1978, 1985-1986

Dental Physiology: 1974-1975

Graduate Mammalian Physiology: 1974, 1986-present
Course Director (1991-present)

Physical Therapy Physiology: 1974-1984

Mathematical Physiology: 1976-1984

Peripheral Vascular Physiology: 1977

Medical Physiology: 1977-present

Physical Principles of Physiology: 1982-1984, 1988-1991, 1993

Advanced Cardiovascular Physiology: 1982, 1984, 1986, 1988, 1990, 1992, 1994

Cardiovascular Dynamics: 1994

Chairman, M-I Cardiovascular Subject Matter Committee: 1981-1987

11.2 Thesis Supervision

Mark D. Okusa, M.S. (1978)

James V. Quinn, M.S. (1978)

David P. Swain, Ph.D. (1984)

Lih Kuo, Ph.D. (1987)

Richard A. O. Bennett, M.S. (1988)

Kaushik Parthasarathi, M.S. (1993)

Daniel W. David, M.S. (1994)

Mei Dong, Ph.D. (current student)

11.3 Postdoctoral Supervision

Joseph V. Boykin, Jr., M.D. (1978-1980)

Sharon M. Sullivan, Ph.D. (1980-1982)

Mary L. Ellsworth, Ph.D. (1982-1985)
Glenn L. Irion, Ph.D. (1985-1988)
Hong Meng, M.D. (1989-1992)
Timothy B. Bentley, Ph.D. (1989-1993)

11.4 Editorial Boards

American Journal of Physiology (Heart and Circulatory Physiology):
1987-1993

Microcirculation: 1993-present

Microvascular Research: 1994-present

11.5 Manuscript Review

American Institute of Biological Sciences
American Journal of Physiology: Cell; Gastrointestinal and Liver;
Heart and Circulatory; Regulatory, Integrative and Comparative
Annals of Biomedical Engineering
Biophysical Journal
Blood Vessels
Circulation Research
Federation Proceedings
IEEE Proceedings of Biomedical Engineering
Journal of Applied Physiology
Journal of Biomechanics
Journal of Cerebral Blood Flow and Metabolism
Journal of General Physiology
Mathematical Biosciences
Microvascular Research
Pflugers Archiv
Science

11.6 Grant Reviews

American Heart Association, Virginia Affiliate, Scientific Review
Committee: 1979-1982, 1986-1991 (Co-chair, 1989; Chair, 1990-1991)

National Science Foundation: 1982, 1984

National Institutes of Health, Program Project Site Visit Team:
University of Pennsylvania (1986), University of New Mexico (1986),
University of Rochester (1987), Duke University (1988), University
of Cincinnati (1991), University of Rochester (1992)

National Institutes of Health, Respiratory and Applied Physiology
Study Section, ad hoc review: 1991

Veterans Administration Career Development Program: 1991

Physicians' Services Incorporated Foundation, Ontario, Canada: 1992

American Heart Association, Arizona Affiliate: 1992, 1993

National Institutes of Health, Clinical Sciences Study Section, ad hoc review: 1992

11.7 Invited Lectures

1974: Biological Seminar, Medical College of Virginia

1975: Department of Medicine, Medical College of Virginia

1976: Department of Experimental Medicine, Pharmacia AB, Uppsala Sweden

1977: Department of Medicine, University of Rochester

Department of Physiology, University of Arizona

Department of Biomedical Engineering, University of Southern California

Department of Physiology, Columbia University

Department of Rehabilitation Medicine, Columbia University

1979: Department of Physiology, Medical College of Virginia

Department of Physiology, University of Arizona

Department of Physiology, University of Virginia

Fall Meeting, American Physiological Society, New Orleans, Louisiana, Symposium on Tissue Oxygen Consumption and Vascular Resistance.

Annual Meeting, American Heart Association, Anaheim, California, Louis N. Katz Basic Science Research Prize Presentation.

Biological Seminar, Medical College of Virginia

1980: Department of Mechanical Engineering, University of Houston

Biomedical Engineering Laboratory, Rice University

Department of Physiology, University of Pennsylvania

Department of Physiology, Columbia University

Department of Radiation Biology and Biophysics, University of Rochester

- 1981: Department of Physiology, University of West Virginia
- 1982: Department of Physiology, University of Texas at San Antonio
- Gordon Conference on Water and Solute Exchange in the Microvasculature, Plymouth, New Hampshire
- 1983: Annual Meeting, Microcirculatory Society, Chicago, Illinois, President's Symposium on Red Cell Flow Distribution and Tissue Oxygenation
- Undersea Medical Society, Oak Ridge, Tennessee, Workshop on Oxygen
- 1984: Department of Physiology, University of Birmingham, Birmingham, England, Symposium on Regulation of Microcirculation in Skeletal Muscle.
- Department of Physiology, Texas Tech University
- 1985: FASEB Meeting, Biomedical Engineering Society, Anaheim, California, Symposium on Engineering and Quantitative Methods in Microcirculation.
- 7th Annual Meeting, International Society for Heart Research Houston, Texas, Symposium on Regulation of the Microvasculature.
- 50th Jubilee Congress, Hungarian Physiological Society, Budapest, Hungary, Symposium on Microcirculation.
- 7th Annual Engineering in Medicine and Biology Society Conference, Chicago, Illinois, Symposium on Microcirculation
- 1986: Department of Physiology, University of Arizona
- Meeting on Oxygen Transport and Delivery Society of Critical Care Medicine, Scottsdale, Arizona
- Department of Medical Physiology, Texas A&M University
- 1987: Microcirculatory Society, Washington, D. C., Symposium on Oxygen Transport and Regulation in the Microcirculation
- Department of Biomedical Engineering, University of Virginia
- Department of Biochemistry and Biophysics, University of Pennsylvania
- 1988: Department of Biomedical Engineering, Johns Hopkins School of Medicine

Canadian Federation of Biological Sciences, Quebec City,
Quebec, Canada, Symposium on Perfusion of Microvascular
Networks by Red Cells

Department of Physiology, Max Planck Institute for
Experimental Medicine, Gottingen, West Germany

1989: IUPS Satellite Symposium on Microvascular Networks, West
Berlin, Germany

Department of Physiology, St. Louis University

1990: Biomedical Engineering Society, Symposium on Rheology and the
Microcirculation, Blacksburg, Virginia

1991: Department of Physiology, University of Arizona

IEEE Southeastcon '91, Williamsburg, Virginia

1992: Department of Physics, Virginia Commonwealth University

Department of Medical Biophysics, University of Western
Ontario, London, Ontario, Canada

Program in Biomedical Engineering, Medical College of Virginia

Department of Biomedical Engineering, Pennsylvania State
University

1993: Critical Issues in Microcirculatory Oxygen Transport,
President-Elect's Symposium, Microcirculatory Society, New
Orleans, Louisiana

Department of Physiology, Osaka University Medical School,
Osaka, Japan

Satellite Symposium on "New Aspects in the Microcirculation,"
First Asian Congress for Microcirculation, Osaka, Japan

Symposium on "Geometry of the Capillary Distribution of
Organs: With Reference to Mass Transfer Processes," First
Asian Congress for Microcirculation, Osaka, Japan

1994: Symposium on "Microcirculatory Exchange in Relation to the
Microvascular Architecture in Different Vascular Beds,"
British Microcirculation Society, London, United Kingdom

Cardiology/Physiology Research Conference, Medical College of
Virginia

11.8 Research Grant Support

A. D. Williams Foundation:	\$2,800 (1974-1975) \$7,500 (1986-1987)
VCU Faculty Grant In-Aid:	\$4,000 (1975-1976) \$7,000 (1985-1986)
American Heart Association: (Capillary Oxygen Transport)	\$32,600 (1975-1978) \$51,000 (1978-1981)
National Institutes of Health: (Vasodilation and Micro- vascular Oxygen Delivery)	\$45,900 (1975-1977) \$152,500 (1977-1982) \$312,200 (1982-1985) \$930,200 (1985-1991) \$1,291,049 (1991-1996)
National Institutes of Health: (Oxygen Transport in Skeletal Muscle Microcirculation)	\$44,200 (1979-1981) \$125,300 (1981-1984)
National Institutes of Health: (Effects of Hypertension: An Integrated Approach - 1 of 4 co-investigators)	\$248,000 (1980-1983)
National Institutes of Health: (Oxygen Sensing by the Vascular Wall)	\$125,000 (1983-1986)

11.9 Other Administrative Experience

Interim Chairman, Department of Physiology, Medical College of Virginia: 1988-1989

12. BIBLIOGRAPHY

12.1 Papers:

- Bashian, A., Finocchiaro, G., Good, M.L., Grannis, P.D., Guisan, O., Kirz, J., Lee, Y.Y., Pittman, R., Fischer, G.C., and Reeder, D.D. Study of the reactions $\pi^+ p \rightarrow K^+ \Sigma^+$ and $\pi^+ p \rightarrow K^+ Y^{*+}(1385)$ between 3.5 and 14 GeV/c. Phys. Rev. D4: 2667-2679, 1971.
- Bashian, A., Finocchiaro, G., Good, M.L., Grannis, P.D., Guisan, O., Kirz, J., Lee, Y.Y., Pittman, R., Fisher, G.C., and Reeder, D.D. Search for peripheral K^+ production in $\pi^- p$ interactions from 2.75 to 10 GeV/c. Phys. Rev. D4: 2600-2683, 1971.
- Pittman, R.N. and Duling, B.R. Oxygen sensitivity of vascular smooth muscle. I. In vitro studies. Microvasc. Res. 6:202-211, 1973.
- Storer, J., Cutts, D., Good, M.L., Grannis, P.D., Green, D., Lee,

- Y.Y., Pittman, R., Benvenuti, A., Fischer, G.C., and Reeder, D.D. Backward pp charge exchange from 1 to 3 GeV/c. Phys. Rev. Lett. 32:950-953, 1974.
5. Pittman, R.N. and Duling, B.R. A new method for the measurement of percent oxyhemoglobin. J. Appl. Physiol. 38:315-320, 1975.
 6. Pittman, R.N. and Duling, B.R. Measurement of percent oxyhemoglobin in the microvasculature. J. Appl. Physiol. 38:321-327, 1975.
 7. Duling, B.R. and Pittman, R.N. Oxygen tension: dependent or independent variable in local control of blood flow? Fed. Proc. 34:2012-2019, 1975.
 8. Pittman, R.N. and Duling, B.R. Effects of altered carbon dioxide tension on hemoglobin oxygenation in hamster cheek pouch microvessels. Microvasc. Res. 13:211-224, 1977.
 9. Cutts, D., Good, M.L., Grannis, P.D., Green, D.D., Lee, Y.Y., Pittman, R., Storer, J., Benvenuti, A., Fischer, G.C., and Reeder, D. D. Antiproton-proton charge exchange between 1 and 3 GeV/c. Phys. Rev. D17:16-23, 1978.
 10. Boykin, J.V., Eriksson, E., and Pittman, R.N. Microcirculation of a scald burn: an in vivo experimental study of the hairless mouse ear. Burns 7:335-338, 1980.
 11. Eriksson, E., Boykin, J.V. and Pittman, R.N. Method for in vitro microscopy of the cutaneous microcirculation of the hairless mouse ear. Microvasc. Res. 19:374-379, 1980.
 12. Lipowsky, H.H., Usami, S., Chien, S., and Pittman, R.N. Hematocrit determination in small bore tubes from optical density measurement under white light illumination. Microvasc. Res. 20:51-70, 1980.
 13. Boykin, J.V., Eriksson, E., and Pittman, R.N. In vivo microcirculation of a scald burn and the progression of postburn dermal ischemia. Plastic Reconstructive Surgery 66:191-198, 1980.
 14. Boykin, Jr., J.V., Eriksson, E., Sholley, M.M., and Pittman, R.N. Histamine-mediated delayed permeability response after scald burn inhibited by cimetidine or cold-water treatment. Science 209:815-817, 1980.
 15. Boykin, Jr., J.V., Eriksson, E., Sholley, M.M., and Pittman, R.N. Cold-water treatment of scald injury and the inhibition of burn edema formation. Surgical Forum, 31:555-557, 1980.
 16. Boykin, Jr., J.V., Eriksson, E., Sholley, M.M., and Pittman, R.N. Cold-water treatment of scald injury and inhibition of histamine-mediated burn edema. J. Surg. Res. 31:111-123, 1981.

17. Sullivan, S.M. and Pittman, R.N. Hamster retractor muscle: a new preparation for intravital microscopy. *Microvasc. Res.* 23:329-335, 1982.
18. Lipowsky, H.H., Usami, S., Chien, S. and Pittman, R.N. Hematocrit determination in small bore tubes by differential spectrophotometry. *Microvasc. Res.* 24:42-55, 1982.
19. Duling, B.R., Damon, D.N., Donaldson, S.R. and Pittman, R.N. A computerized system for densitometric analysis of the microcirculation. *J. Appl. Physiol.* 55:642-651, 1983.
20. Ellsworth, M.L. and Pittman, R.N. Heterogeneity of oxygen diffusion through hamster striated muscles. *Amer. J. Physiol.* 246:H161-H167, 1984.
21. Sullivan, S.M. and Pittman, R.N. In vitro resting oxygen uptake (VO_2) and histochemical fiber type of hamster muscles. *J. Appl. Physiol.* 57:246-253, 1984.
22. Pittman, R.N. In vivo photometric analysis of hemoglobin. *Ann. Biomed. Eng.* 14:119-137, 1986.
23. Pittman, R.N. Interaction between oxygen and the blood vessel wall. *Can. J. Cardiol.* 2:124-131, 1986.
24. Pittman, R.N. and Ellsworth, M.L. Estimation of red cell flow in microvessels: consequences of the Baker-Wayland spatial averaging model. *Microvasc. Res.* 32:371-388, 1986.
25. Ellsworth, M.L. and Pittman, R.N. Evaluation of photometric methods for quantifying convective mass transport in microvessels. *Amer. J. Physiol.* 251:H869-H879, 1986.
26. Sullivan, S.M. and Pittman, R.N. Relationship between mitochondrial volume density and capillarity in hamster muscles. *Amer. J. Physiol.* 252: H149-H155, 1987.
27. Ellsworth, M.L., Pittman, R.N. and Ellis, C.G. Measurement of hemoglobin oxygen saturation in capillaries. *Amer. J. Physiol.* 252:H1031-H1040, 1987.
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29. Kuo, L. and Pittman, R. N. Effect of hemodilution on oxygen transport in arteriolar networks of hamster striated muscle. *Amer. J. Physiol.* 254:H331-H339, 1988.
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- impact of heterogeneities of convective oxygen transport parameters in capillaries of striated muscle: experimental and theoretical. *Microvasc. Res.* 35:341-362, 1988.
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 32. Popel, A.S., Pittman, R.N. and Ellsworth, M.L. The rate of oxygen loss from arterioles is an order of magnitude higher than expected. *Amer. J. Physiol.* 256: H921- H924, 1989.
 33. Ellis, C.G., Ellsworth, M.L. and Pittman, R.N. Determination of red blood cell oxygenation in vivo by dual video densitometric image analysis. *Amer. J. Physiol.* 258:H1216-H1223, 1990.
 34. Ellsworth, M.L. and Pittman, R.N. Arterioles supply oxygen to capillaries by diffusion as well as by convection. *Amer. J. Physiol.* 258:H1240-H1243, 1990.
 35. Weerappuli, D.P.V., Pittman, R.N. and Popel, A.S. Effect of convection in capillaries on oxygen removal from arterioles in striated muscle. *J. Theor. Biol.* 147:275-288, 1990.
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